INDEPENDENT PROJECT ANALYSIS, INC.

New Technology and Solids:

A Difficult Combination

U.S. DOE

Slurry Retrieval, Pipeline Transport & Plugging, and Mixing Workshop

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Confidentiality

- **Much of the information is confidential to IPA**
- **Less detailed version of briefing will be provided later**

Purpose of this Presentation

- DOE has an ambitious and difficult waste processing mission
- Demonstrated methods will often not exist
  - New technology must be developed
- Most of the materials will not behave well
- Combination of poorly behaved materials and new technology often leads to failure
- Failure has severe consequences

Degree of Innovation Matters

- Each new step, on average, reduces operability ~10 percent in months 7 – 12 for all types of facilities
- Each new step, on average, increases startup duration by ~2 months for all types of facilities
  - ~3 months for solids processing facilities
- Facilities with three or more new steps are at much higher risk of outright failure
- More innovative and complex technologies need more extensive development facilities

Outline

- IPA background and methodology
- Industry history with similar projects
- DOE project history
- Reasons for project failure
- Best Practices for success
- Conclusions

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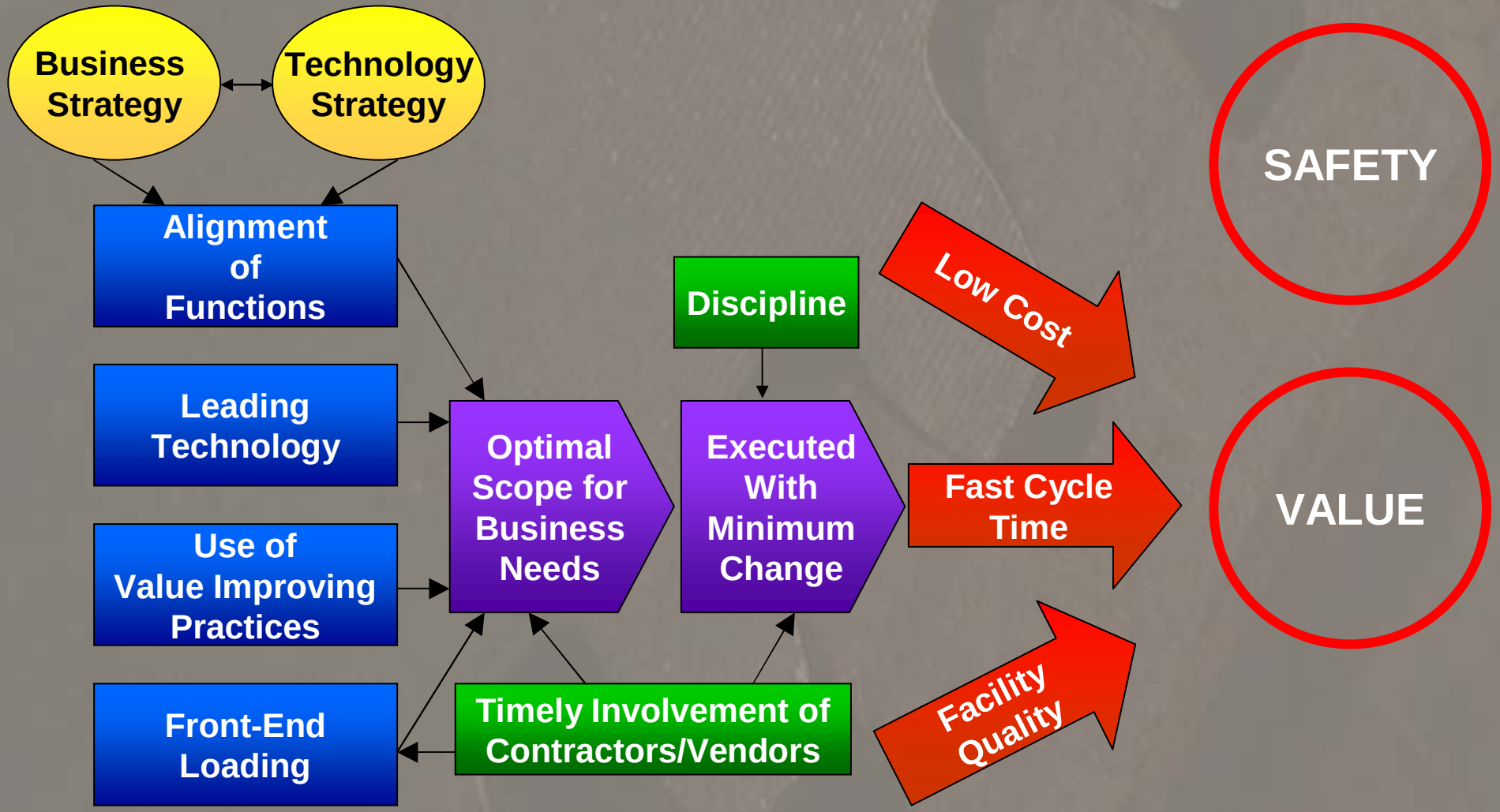
IPA Background

- Independent Project Analysis (IPA) evaluates capital projects for the processing industries around the world
  - Benchmarking and Best Practices company
  - Work for most of the major oil and chemical companies
- Started 20 years ago
  - Original work began about 10 years before that at Rand
  - Much of the original work was for DOE
- Now nearly 200 employees
- We collect detailed project histories of about 800 projects each year
- We now have detailed databases of about 11,000 process facilities

Elements of Capital Effectiveness



Database (1)

- Total of about 12,000 projects
  - Average start of execution: 1Q2000
  - Size range: $15k – $10B
  - Process facilities, non-process facilities, E&P projects, etc.
  - About 150 DOE projects (DP and WM) from the ’70s, ’80s, and ’90s
- About 1,000 projects with new technology
- About 1,700 projects with solids processing

Database (2)

- Our goal is to examine difficulties in solids processing and innovation
- Therefore, we selected samples heavily weighted toward new technology projects
- Focus on major projects rather than smaller, plant-based projects
- We will use minerals industry as a proxy
  - Difficult materials handling
  - Materials typically cannot be characterized well—raw solids
  - Difficult processing

Some Definitions

- **Startup:** the period from mechanical completion of facilities (all units physically able to run) to routine operation
  - Facilities are making on-spec product but may not have achieved sustainable nameplate
- **Early operability:** production as a percent of nameplate capacity in months 7 through 12 after mechanical completion
- **New steps:** processing steps (chemical or physical) that are new in commercial use
  - New equipment, new match of equipment and feed, new chemical processing
- **Heat and Material Balances Known:** portion of balance equations for plant/processing train based on commercial experience

Defining New Technology (1)

- New process technology is any of the following:
  - Process chemistry that has not been used commercially
  - Incorporation of major equipment that is commercially unproven
  - New match of feed and equipment
- Scale-up of commercially proven technology is not new
- “New-to-company” is not necessarily new

Defining New Technology (2)

- IPA measures new technology in several ways:
  - Number of process steps that use new technology
  - Percentage of investment in new technology
  - Technology stepout scale

Technology Stepout Scale (1)

- **Off the shelf technology**
  - **Project nearly duplicates proven process with modifications confined to site tailoring**
- **New integrations only**
  - **New configurations of existing, commercially proven process steps**
- **Minor process modification**
  - **One or more steps are new but order and functions of steps are unchanged from current practice**

Technology Stepout Scale (2)

- **Major process modification**
  - **Two or more steps new but core technology unchanged or can be isolated from up- and downstream**
- **Substantially new process**
  - **Analogous process may be in use but this is new path or approach**
  - **Core technology new and effects cannot be isolated**
- **All new process**
  - **No process like this one in use anywhere**
  - **Many steps new or substantially changed from prior plants**

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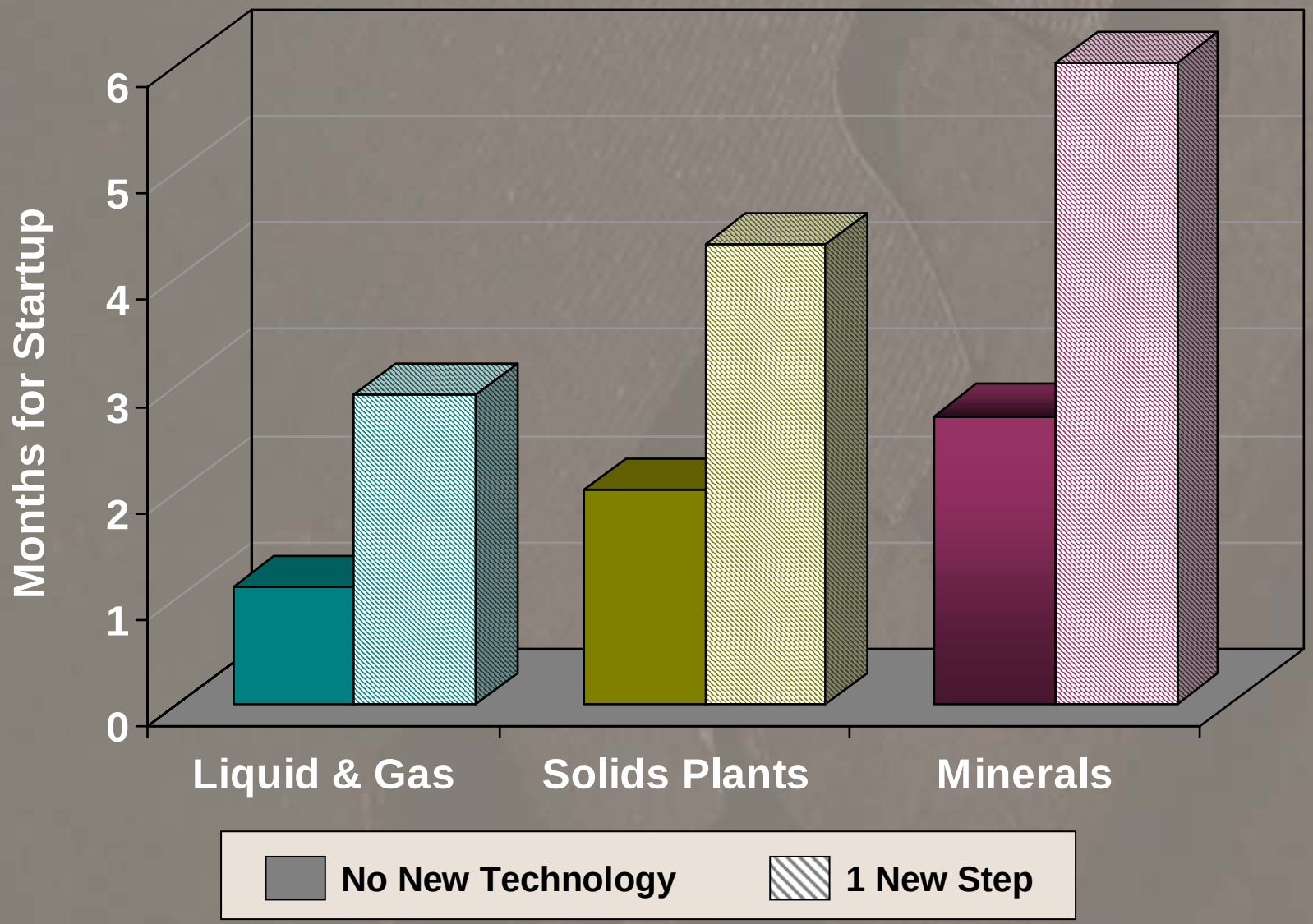
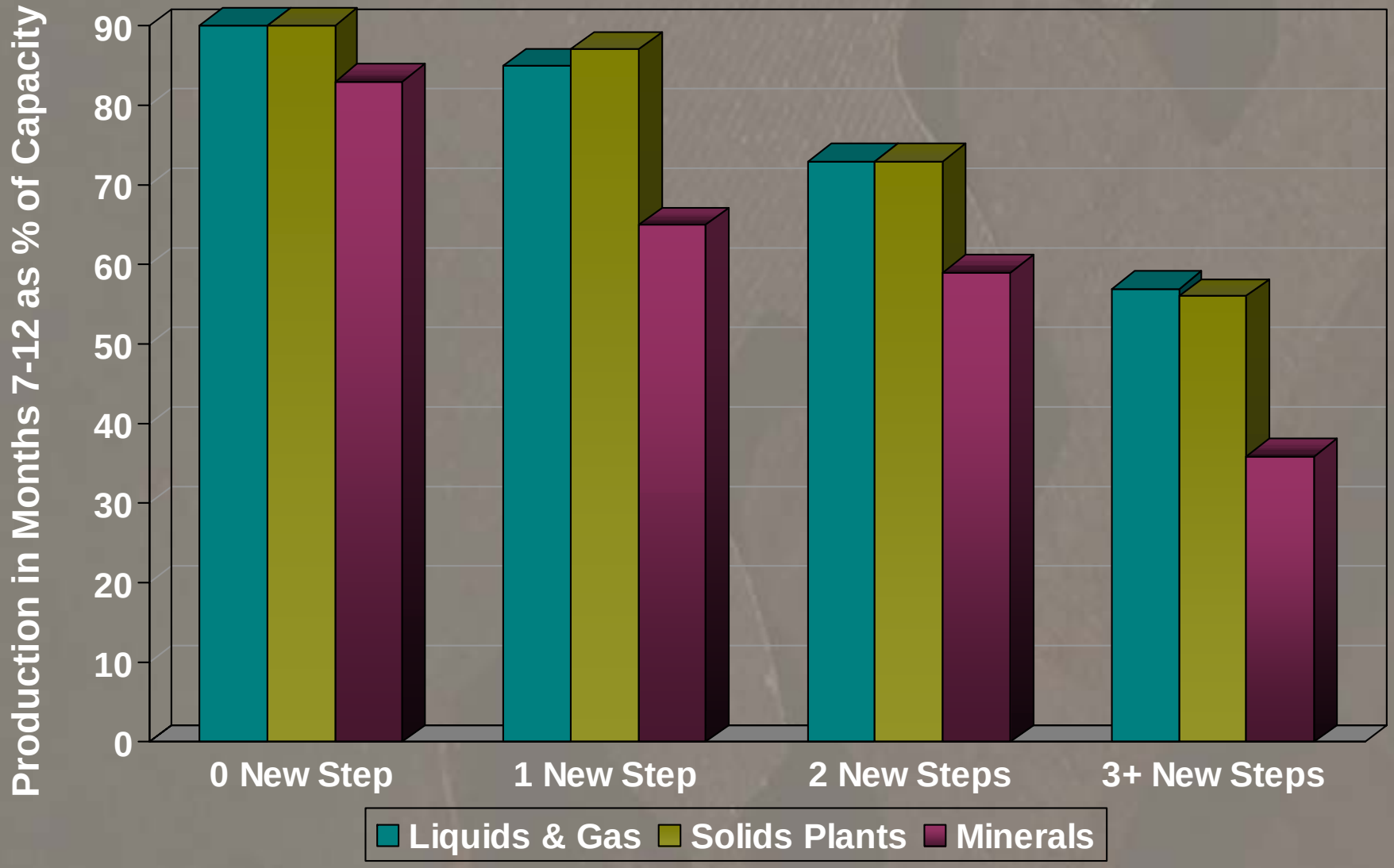
What History Tells Us...

- Many introductions of new technology have been business disasters!
- New technology substantially increases project failure chances
- Historically, new technology is linked with:
  - Much higher average cost growth
  - Difficult startups
  - Poorer operability
  - >40 percent of moderate and high innovation efforts were outright failures
  - <20 percent delivered all of what was promised
- Difficulties can be (partially) mitigated by proper understanding and management

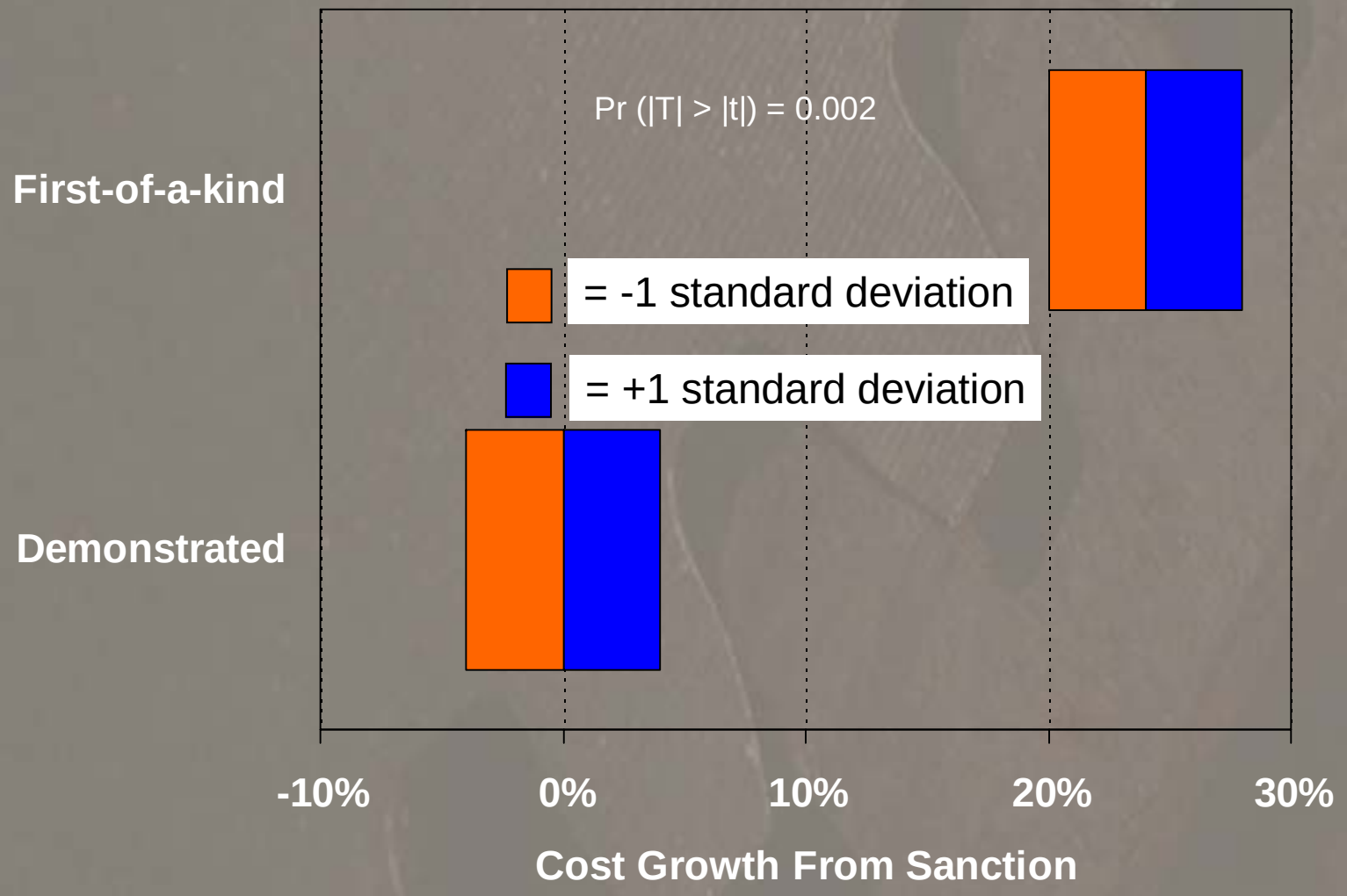
Startup Time



New Technology and Minerals Are a Difficult Mix



Cost Growths of First-of-a-Kind Processes Are Greater Than Ones Previously Demonstrated



Not controlled for other factors

What's Behind the Difficulties?

- **Waste handling problems**
- **Feedstock impurity problems**
- **Weak basic technical data**

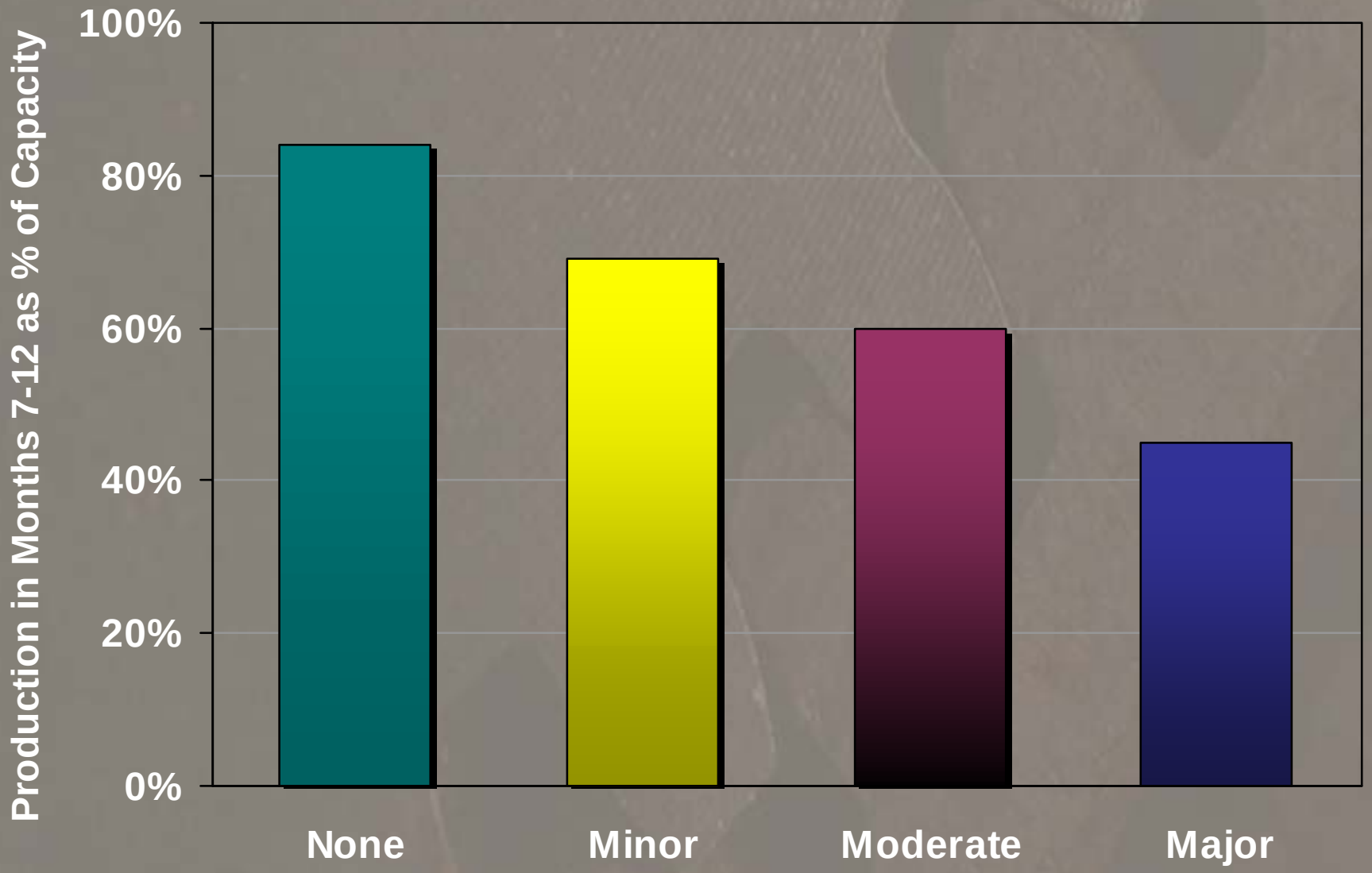
Waste Handing Problems

- 40 percent of innovative minerals processing facilities experience waste handling or treatment problems in startup
  - Versus 24 percent of other innovative process plants (pr<.01)
- In non-minerals processing plants, effects were short-lived and did not affect operability in 3rd and 4th quarters
- In minerals processing facilities, waste handling problems were associated with losses up to 22 percent of capacity in the 2nd six months (pr.<.0001)

Unexpected Impurities in Feedstocks

- **Feedstock impurities are more common in minerals processing than chemical processing generally**
- **When they occur, they punish early operability severely, regardless of the level of innovation**

Feedstock Impurity Problems Damage Performance in Minerals



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DOE Benchmarking

- IPA benchmarked DOE projects at least twice
  - Defense Programs in 1990
  - Waste Management in 1995
- Project performance substantially lagged Industry
  - Poor cost predictability
  - Long schedules with substantial slip
  - Long startups and below nameplate operation

Why?

- Long DOE funding cycle
  - Disrupted team continuity
  - Made FEL uncertain
- Changing objectives
- Frequent lack of commercially available solutions
- Fundamentally more difficult problems
  - But even simple projects suffered the same problems

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Weak Basic Technical Data

- Unlike liquids and gases, data for minerals processing do not scale well from smaller experimental facilities
- Minerals facilities are intrinsically more difficult to instrument than liquid and gas processing facilities making data less available from prior units
- Ambient conditions affect minerals handling and processing characteristics in ways that are unusual with liquids and gases
- As a result, basic technical data are weak for new technology minerals processing plants
- Consequences are seen in plant operability

Why Do New Technology Projects Fail?

- **Push for speed prevents obtaining necessary basic data**
  - **As a result, everything is fast-tracked except startup**
  - **Shortcuts that lead to failure:**
    - > **Skipping the integrated pilot**
    - > **Short-cutting FEL**
    - > **Accelerating execution**

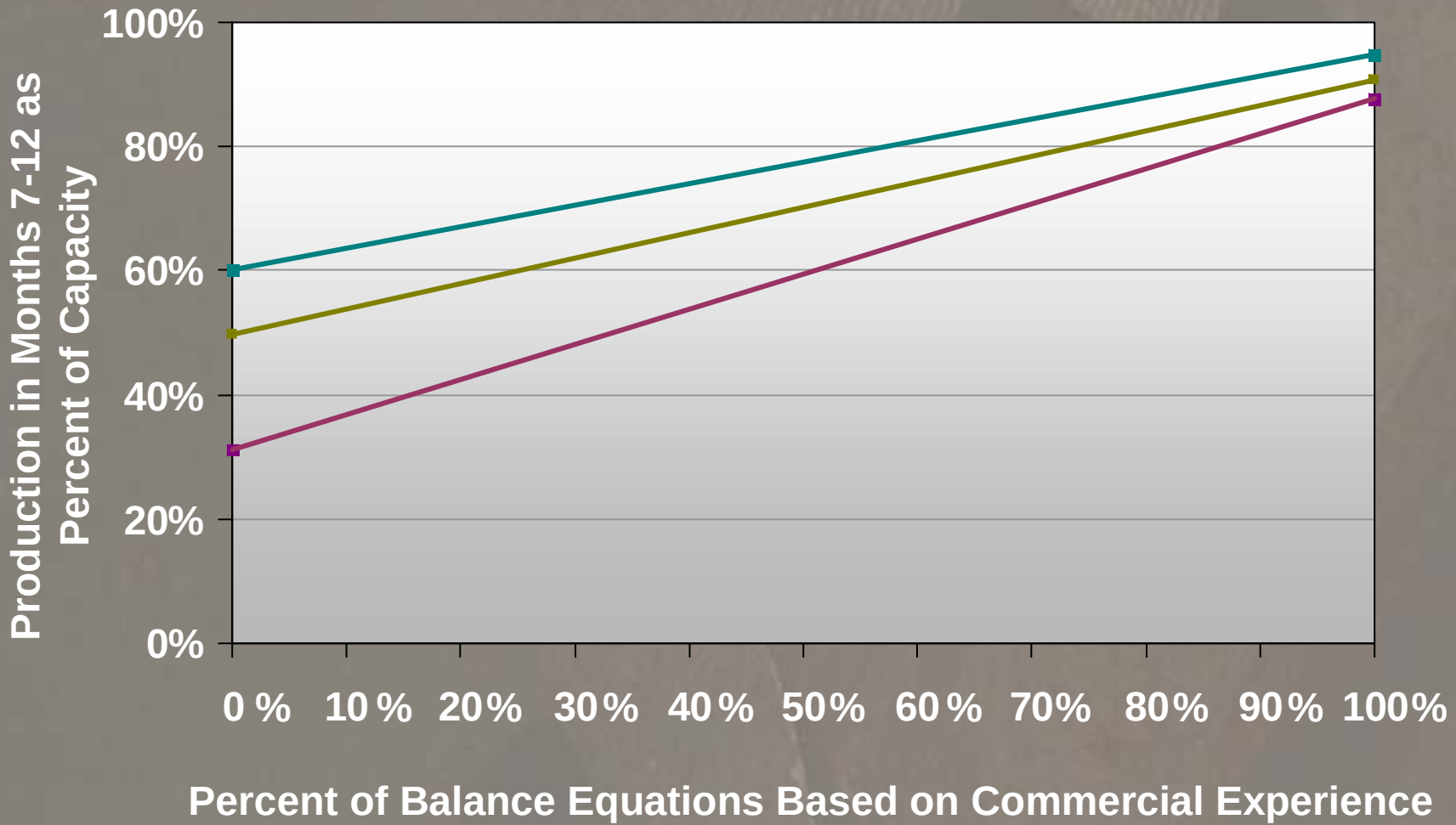
Basic Data Are Basic!

- If basic data are wrong, the design will be flawed, often in fundamental way
- Because basic data underpin design, design conservatism does not help
  - You cannot engineer your way out of bad basic data
- Errors in basic data are the most common cause of failed new technology projects

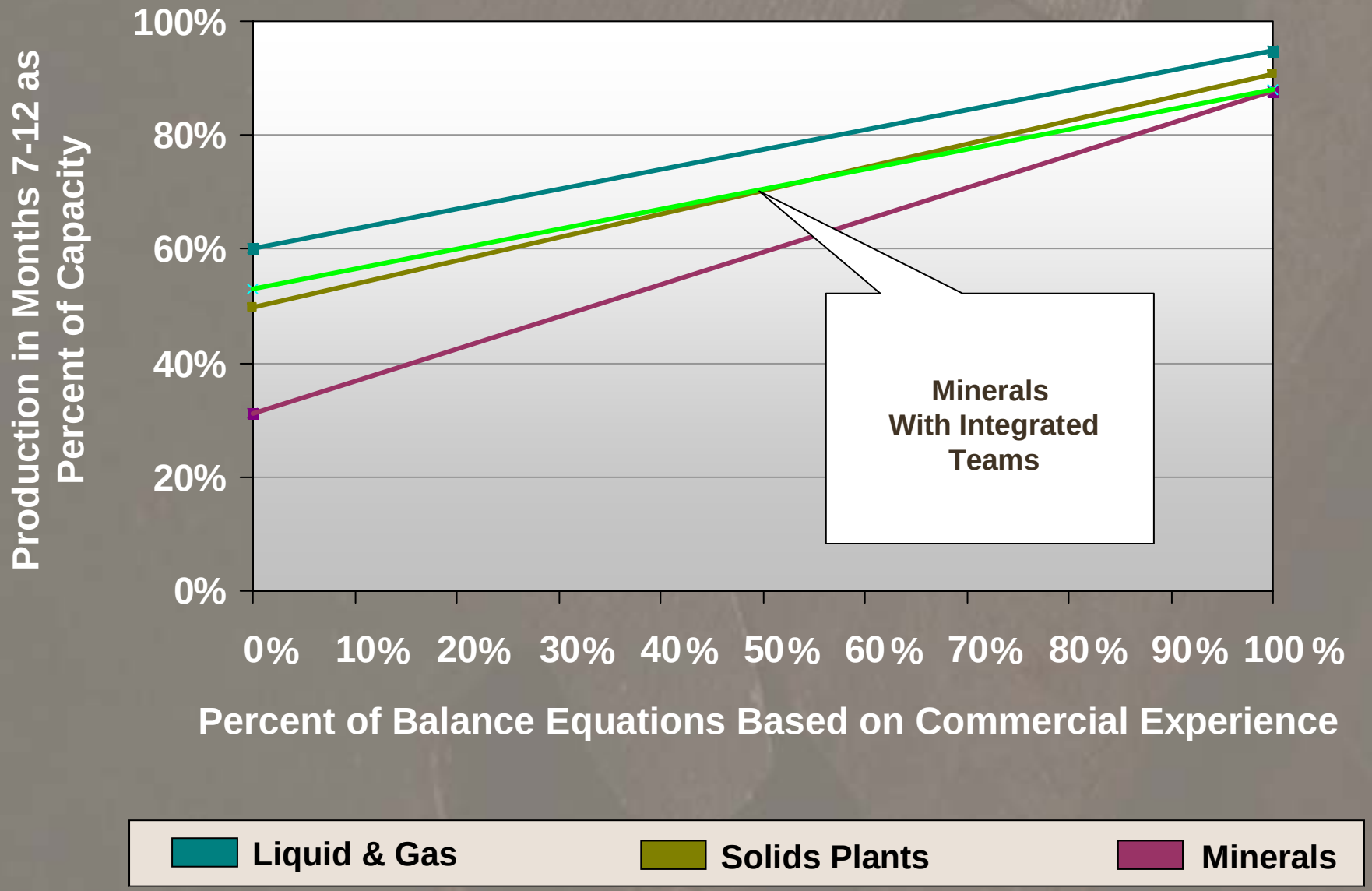
Good Engineering Cannot Substitute for Complete Basic Data

- Reaction products, especially side reaction products
- Separation technology verified
- Heat and mass balances established
- Materials of construction (corrosion and erosion cannot be simulated)
- Temperature and pressure control
- Engineered equipment specifications
- Mechanical equipment selection

H&M Balance Knowledge Is Critical for Minerals Operability



But H&M Balance Knowledge Is Critical for Minerals Operability



Processing Solids

- Solids hate mechanical equipment and seek to destroy it by force
- Solids processing is highly empirical
- Processing characteristics cannot be safely predicted from theory or small-scale experiments
  - Behavior of solids under process conditions often scale-dependent
    - > Fluid beds change characteristics with size
    - > Slurry reactors experience wall effects
    - > Speeds required at scale induce carryover of materials

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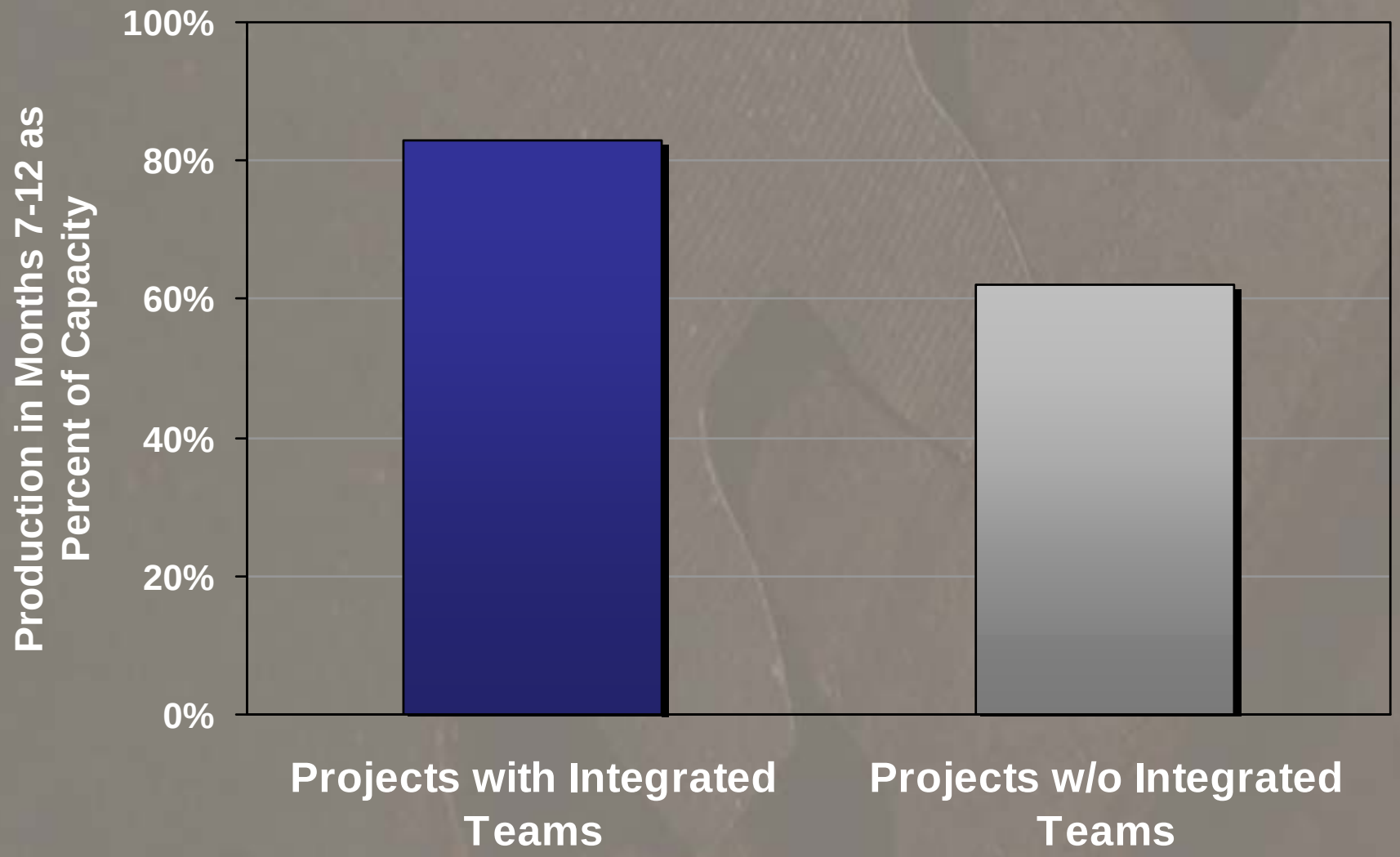
Defining the Integrated Project Team

- An integrated project team has all owner functions fully represented on the team starting in front-end loading. At least the following are present:
  - Environmental
  - Planning & Scheduling
  - Geology
  - Mine Eng./planning
  - Business
  - Engineering
  - Construction
  - R&D
  - Maintenance
  - Mine/Plant operations
  - Health & Safety
  - Startup
- These team members are identified prior to project authorization and have specific responsibilities that are defined and understood by all team members
- The team members have the authority to make decisions for their function
- Reasonable continuity must be maintained

Staffing New Technology Programs

- **Three critical factors in new technology staffing:**
  - **Core team should have continuity from pilot(s) through commercialisation of first unit**
  - **Core team must include science/technology base, solid project expertise, and high-quality process engineers**
  - **Additional resources must be made available as needed and requested**

Team Integration Directly Improves Operability of Minerals Plants



Team Integration also...

- **Reduces deleterious effects of not knowing the heat and material balances by 45 percent!**
- **Reason is straightforward:**
  - **If you lack strong empirical basis, next best substitute are knowledgeable people, especially operations, maintenance, startup, and core R&D personnel**

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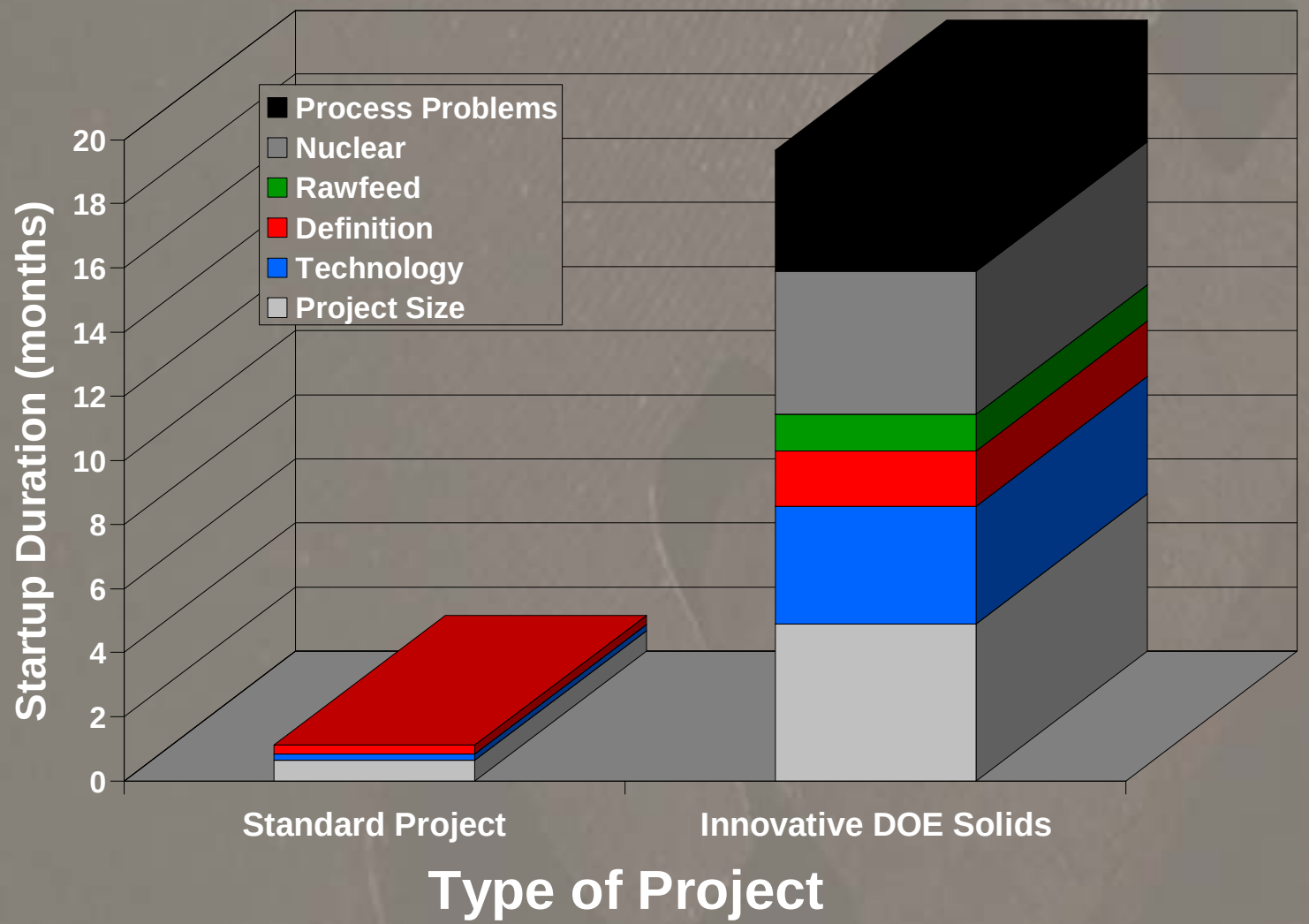
Summing Up

- **Raw solids processing projects face some unique challenges when trying to introduce new technology**
  - **Problems that are easily resolved in other types of processing such as waste handling and feedstock problems are more stubborn**
  - **Transfer of basic technical data from prior plants is both more important and more difficult**

What Does This All Mean for a DOE Project Startup?

- $100 million project
- DOE project:
  - Minor process modification with 2 new steps (6 total)
  - Medium level process problems
  - Nuclear
  - Raw solid feed
  - Poor FEL
- Industry (non-nuclear) project
  - No new technology, so no process problems
  - 6 total process steps
  - No raw solid feed
  - Good FEL

Startup Duration Example



Some Don’ts of New Technology Program Management

- Remember, most R&D is just plain work and can be planned, scheduled, and resourced as such
- Don’t substitute good engineering for bad basic data
  - All you get is a conservatively designed, inoperable plant
- Never fast-track R&D
- Never fast-track new technology projects

More Don’ts

- Don’t understate risks to get approval
- Don’t do new technology projects without doing excellent front-end definition; risks will kill you
- Don’t mismatch business objectives and new technology development realities
  - If success requires short-cutting to achieve cycle time, cancel the project
  - If business goal is an incremental improvement, a long, costly R&D effort will never work

Thank you for your attention!